

Reciprocal Altruism-based Cooperation in a Social Network Game

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Abstract Cooperative behaviors are common in humans and are fundamental to our society. Theoretical and experimental studies have modeled environments in which the behaviors of humans, or agents, have been restricted to analyze their social behavior. However, it is important that such studies are generalized to less restrictive environments to understand human society. Social network games (SNGs) provide a particularly powerful tool for the quantitative study of human behavior. In SNGs, numerous players can behave more freely than in the environments used in previous studies; moreover, their relationships include apparent conflicts of interest and every action can be recorded. We focused on reciprocal altruism, one of the mechanisms that generate cooperative behavior. This study aims to investigate cooperative behavior based on reciprocal altruism in a less restrictive environment. For this purpose, we analyzed the social behavior underlying such cooperative behavior in an SNG. We focused on a game scenario in which the relationship between the players was similar to that in the Leader game. We defined cooperative behaviors by constructing a payoff matrix in the scenario. The results showed that players maintained cooperative behavior based on reciprocal altruism, and cooperators received more advantages than noncooperators. We found that players constructed reciprocal relationships based on two types of interactions, cooperative behavior and unproductive communication.

§1 Introduction

Cooperative behaviors are common in humans, and they are fundamental to our society^{9, 24)}. However, noncooperators obtain more advantages than cooperators during interactions, because cooperators tend to be exploited by noncooperators²⁾; thus, natural selection should favor noncooperators. Nevertheless, humans cooperate with each other; therefore, they must have acquired mechanisms that ensure cooperation during the evolutionary process⁴⁾.

Since cooperators tend to be exploited by noncooperators, these evolutionary dynamics require structured interactions in which cooperators interact more frequently with cooperators and noncooperators interact more frequently with noncooperators. Thus, humans must have acquired mechanisms for assortment between cooperators and noncooperators during the evolutionary process. Five theoretical mechanisms have been proposed¹⁷⁾: kin selection, direct reciprocity, indirect reciprocity, spatial selection, and multilevel selection. Theoretical and experimental studies have presented evidence of these mechanisms²¹⁾. Evidence has been acquired using modeled environments with constrained behaviors of humans, or agents, to analyze their social behavior explicitly. However, it is important that this evidence be generalized to a less restrictive environment to understand human society²¹⁾.

Interactive online games are particularly powerful tools for the quantitative study of human society^{6, 3, 26, 25, 27)}. In online games, numerous players can behave more freely than is possible in the environments used in the theoretical and experimental studies^{17, 21)}, i.e., they do not need to select from a sequence of several alternatives, because they always have multiple alternatives. In addition, the actions of all players can be recorded. In the present study, we analyzed a social network game (SNG), such as *Rage of Bahamut*,^{*1} or *Girl Friend BETA*,^{*2} to understand cooperative behavior among humans, because the following features of SNGs provide easier analysis of cooperative behavior. SNGs allow real players to cooperate and compete with others in situations when the player's benefit is represented by a quantitative value, such as a payoff in game theory.

We focused on cooperation based on direct reciprocity (reciprocal altruism)²⁹⁾. The mechanism is a behavior whereby an individual acts in a manner that temporarily reduces its fitness, while increasing another individual's fitness, with the expectation that the other individual will behave in a similar manner

*1 <http://mobage.com/games/rage-of-bahamut>

*2 <http://vcard.ameba.jp>

at a later time. This behavior has been observed in humans^{10, 11, 20)} and other primates¹⁹⁾. In addition, the possibility of this behavior has been suggested even in vampire bats³⁰⁾ and fishes⁵⁾. Evolutionary game theory studies have also shown that reciprocal altruism drives the evolution of cooperation^{15, 18, 2)}.

Cooperation based on reciprocal altruism requires the following three conditions: 1) a long-term social relationship between individuals, 2) the capacity for individual recognition and memory of others' behavior, and 3) greater benefits from cooperation than costs of cooperation. If these conditions are satisfied, then an individual can judge whether interactions with another individual will provide benefits. Thus, cooperators increase their future benefits by cooperating with reciprocal cooperators. Simultaneously, it is difficult for noncooperators to interact with cooperators, because cooperators tend to select cooperators as interaction partners¹²⁾. Consequently, this may work as punishment inhibiting defective behavior by reciprocal cooperators with noncooperators²²⁾.

This study aims to investigate reciprocal altruism that generates cooperative behavior in a less restrictive environment. For this purpose, we analyzed the effects of reciprocal altruism in an SNG, in which players could behave more freely than was possible in the environments used in the theoretical and experimental studies. Players competed and cooperated with each other in the SNG. In such an environment, players (i.e., humans) obviously have the capacity for individual recognition and the memory of others. Therefore, cooperation based on reciprocal altruism is expected to emerge in an SNG, because the above conditions are met. In this paper, we first confirmed the presence of cooperation based on reciprocal altruism. Then, we analyzed its effects to determine their benefits, and explored factors that reinforced cooperative behavior.

§2 Materials and Methods

In this section, we provide the minimal SNG information and the definition of cooperative behavior in an SNG (see appendices §1, §2, and §3 for game information, rules, and definition, respectively).

We analyzed cooperative behavior in the SNG, "Girl Friend BETA," in which players acquired "event points" and competed in the rankings based on those points, because the players received better awards as their rankings increased. The player's ranking order was determined by the sum of event points obtained in the period from 3/25/2013 to 4/8/2013. It was impossible to analyze societal dynamics in this SNG, because the rules changed frequently. The situ-

ation in the SNG was also unstable in the early stage of this period; therefore, for simplification, we used only the data from the final three days.

The event points for players' actions correlate significantly with their levels, one of a player's attributes^{*3}. Players must spend their energy to obtain event points; therefore, the number of players' actions is finite. There are two methods for replenishing these points, waiting for the points to replenish over time and using a paid item. Let "payment amount" be the sum of money spent by each player during the analysis period. Players must use their resources (items and time) effectively to progress to a higher ranking, because any player's time and money are finite.

Players belong to groups limited to 1-50 players. The SNG is designed to ensure that cooperation with group members results in an effective game play. Players can communicate at any time through simple text messaging. This does not negatively affect either senders or receivers; nevertheless, its positive effects are also few^{*4}. We targeted groups of five or more active players who logged in at least one or more times to analyze social interactions. In addition, we limited data to intragroup communication and cooperation.

Table 1 Payoff matrix of leader game, where $S + T > 2R$ and $T > S > R > P$, i.e., Pareto efficiency is achieved, when one cooperates and the other does not cooperate. Then the cooperator obtains S , and the noncooperator T .

	Cooperation	Noncooperation
Cooperation	R, R	S, T
Noncooperation	T, S	P, P

We analyzed cooperative behavior based on reciprocal altruism in the above environment. It was difficult to track all cooperative behavior, because players can exhibit various behaviors in the SNG. Hence, we selected a specific cooperative behavior among various cooperative behaviors and regarded the frequency of that behavior as a measure of a player's cooperativeness.

^{*3} Accurately, the event points per player's action depend primarily on players' attack power, which strongly correlates with their levels. The game did not store to a log file, hence we used players' levels as alternatives.

^{*4} Players acquire a few points for a lottery that provides a card, when the players send messages to other at the beginning of each day. However, players must pay 200 points for the lottery, and the effect of the card is small, i.e., the points do not increase players' abilities.

We focused on a game scenario in which the relationship between players was similar to that in the Leader game (Table 1), but it was not possible for both players to cooperate at the same time in this scenario (see appendix §3). In the Leader game, Pareto efficiency is achieved, when one player cooperates and the other does not. Then the cooperator receives S , and the noncooperator T . That is, players receive a high payoff by sharing S and T on repeated plays of the game, a process known as ST reciprocity²⁸⁾. We recognized this cooperative behavior, which provides the payoff S to the other, as a cooperative behavior in this scenario.

§3 Results

First, we confirm the presence of cooperation based on reciprocal altruism. We define the degree of reciprocity between player i and player j for this analysis as follows:

$$r_{ij} = \min(C_{ij}, C_{ji}) / \max(C_{ij}, C_{ji}), \quad (1)$$

where C_{ij} are the number of cooperative behaviors from player i to player j , C_{ji} are the number of cooperative behaviors from player j to player i , i.e., r_{ij} is asymptotic to one, when they mutually cooperate, and to zero, when one cooperates with the other and the other does not cooperate in return. r_{ij} was observed, when $C_{ij} > 0$ or $C_{ji} > 0$.

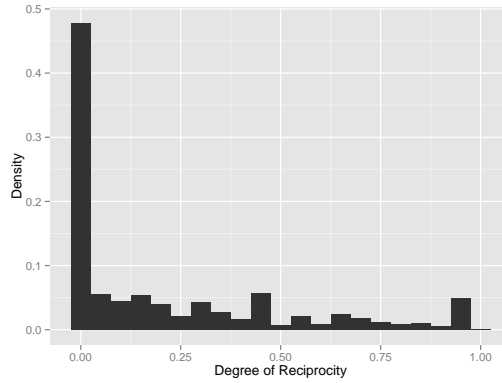


Fig. 1 Density distribution of degree of reciprocity r_{ij} .

Figure 1 shows the density distribution of r_{ij} . The mode was 0.0 (i.e., nonreciprocal relationship). However, there were also some large values of r_{ij}

Table 2 The results of the regression analysis of event points p_i . ***, **, * indicate that the signs of regression coefficients did not change in a Wald-type 99.9%, 99%, and 95% confidence interval (the symbols show the same meaning in the following figures).

Explanatory Variable	Regression Coefficient	Standard Error
$\ln s_i$	0.3481788	(0.0060875)***
L_i	0.0275284	(0.0003245)***
f_i	0.1523005	(0.0080843)***
Intercept	10.004722	(0.0411644)***

(i.e., reciprocal relationship). We regarded this relationships as reciprocal when $r_{ij} > 0.0$.

Second, we describe the effects of reciprocal relationships in regard to the benefits. The number of reciprocal relationships f_i is expected to affect the number of event points p_i positively, if cooperation based on reciprocity is effective in the SNG. Consider the following generalized linear model (GLM) to analyze the effect.

$$p_i \sim \text{NB}(r_i), \quad (2)$$

$$\ln r_i = \beta_1 \ln s_i + \beta_2 L_i + \beta_3 f_i + \beta_4.$$

This model is intended to explain the event points p_i of player i by player's level L_i and the number of reciprocal relationships f_i . We also use the log of the payment amount for items s_i , because paid items proportionally increase the number of actions intended to obtain event points. $\text{NB}(x)$ shows that x follows a negative binomial distribution. We used a log link function and estimated its parameters using the maximum likelihood method with 5,000 players whose $s_i > 0$, sampled at random. In the following analysis, we used the same link function and the same method of estimating parameters. We considered this model and a generalized linear mixed-effects model (GLMM) with a Poisson distribution, because the data showed over-dispersion when the GLM with a Poisson distribution was applied, then Akaike information criterion (AIC) selected this model.

Table 2 shows the analysis results of the model. The regression coefficient of f_i was positive, even after controlling for s_i and L_i , i.e., a player with many reciprocal relationships received more event points than others with the same s_i and L_i . Thus, reciprocal relationships increased the efficiency of payment, i.e.,

Table 3 Results of regression analysis for cooperation between players.

Explanatory Variable	Regression Coefficient	Standard Error
$\ln C'_i C_j$	0.6210306	(0.0041205)***
C_{ji}	0.0122157	(0.0006525)***
g_{ij}	-0.0008443	(0.0004852)
g_{ji}	0.0021324	(0.0004206)***
L_i	0.0004757	(0.0002047)*
L_j	-0.0019128	(0.0001950)***
m_i	-0.1066716	(0.0022965)***
Intercept	-0.1003971	(0.0283909)***

the relationships increased players' benefits.

Third, we report factors that drove the reciprocal relationships. Consider the following GLMM to analyze the factors:

$$\begin{aligned}
 C_{ij} &\sim \text{Poisson}(\lambda_{ij}), \\
 \ln \lambda_{ij} &= \beta_1 \ln C'_i C_j + \beta_2 C_{ji} + \beta_3 g_{ij} + \beta_4 g_{ji} \\
 &\quad + \beta_5 L_i + \beta_6 L_j + \beta_7 m_i + \beta_8 + \sigma_i.
 \end{aligned} \tag{3}$$

This model is intended to explain the number of cooperative behaviors from i to j (C_{ij}) by the number of cooperative behaviors from j to i (C_{ji}), the frequency of messaging g_{ij} and g_{ji} , both players' levels L_i and L_j , their group size m_i , and the random effects of their group σ_i . In addition, we use the log of the product of C'_i and C_j , which respectively shows the total number of cooperative behaviors of others with i and the total number of cooperative behaviors j with others, because this value is expected to increase C_{ij} proportionally, if players cooperate at random. That is, this model estimates the effects of these explanatory variables on C_{ij} comparing the random behavior. $\text{Poisson}(x)$ shows that x follows a Poisson distribution. We estimated its parameters with 30,000 relationships between players whose $C'_i, C_j > 0$, sampled at random. We considered this model and a GLM with a negative binomial distribution, because the data showed over-dispersion when the GLM with a Poisson distribution was applied, then AIC selected this model.

Table 3 shows the analysis results of the model. The regression coefficient of C_{ji} and g_{ji} were positive, even after controlling for C_j , C'_i , L_i and L_j , i.e., to receive cooperation from others, it was important for players to cooperate with

each other and to receive communications from others. In addition, this trend was stronger with smaller groups, because m_i was negative.

Finally, we analyzed the effects of players' social relationships on their social behavior in win-win situations, in which responding to a "help" request from group members provides benefits to both the helper and the helped players (see appendix §4). Then, the helper can obtain benefits even by helping someone. We estimated the social relationships effect on whether a player who receives a help request responds to the request. Consider the following GLM to analyze the effect of reciprocal relationships:

$$\begin{aligned} H_{ij} &\sim \text{NB}(r_{ij}), \\ \ln r_{ij} &= \beta_1 \ln H'_i H_j + \beta_2 C_{ji} + \beta_3 g_{ij} + \beta_4 g_{ji} \\ &\quad + \beta_5 L_i + \beta_6 L_j + \beta_7 m_i + \beta_8. \end{aligned} \tag{4}$$

This model is intended to explain the number of help requests from i to j (H_{ij}) by the number of help requests from j to i (H_{ji}), the frequency of messaging g_{ij} and g_{ji} , both players' levels L_i and L_j , and their group size m_i . In addition, we used the log of the product of H'_i and H_j , which respectively shows the total number of help requests from others to i and from j to others, because this value is expected to increase H_{ij} proportionally, if players respond to help requests at random. That is, this model estimates the effects of these explanatory variables on H_{ij} comparing the random behavior. $\text{NB}(x)$ shows that x follows a negative binomial distribution. We estimated its parameters using 30,000 relationships between players who satisfied $H'_i, H_j > 0$, sampled at random. We considered this model and a GLMM with a Poisson distribution, because the data showed over-dispersion when the GLM with a Poisson distribution was applied, then AIC selected this model.

Table 4 shows the analysis results of the model. The regression coefficient of C_{ji} , g_{ij} and g_{ji} were positive, even after controlling for H_j , H'_i , L_i and L_j , i.e., in order to get helps from others, it was important to cooperate with each other and to communicate each other. Additionally, this trend was stronger in smaller groups because m_i was negative. Thus, players selected partners who were cooperative for them even in the win-win situation.

§4 Discussion

In the present study, we analyzed social behavior in the SNG to understand reciprocal altruism, one of the mechanisms that generate cooperative

Table 4 Results of the regression analysis for response to help requests.

Explanatory Variable	Regression Coefficient	Standard Error
$\ln H_i' H_j$	0.8891775	(0.0064618)***
C_{ji}	0.0066710	(0.0018601)***
g_{ij}	0.0089753	(0.0007516)***
g_{ji}	0.0066472	(0.0007328)***
L_i	0.0063142	(0.0002365)***
L_j	-0.0046951	(0.0002432)***
m_i	-0.0692416	(0.0012895)***
Intercept	-0.4414666	(0.0218464)***

behavior. We showed the presence of reciprocal relationships with players who had reciprocal relationships receiving more benefits than others. That is, this SNG could be used to explore the mechanism of the emergence of reciprocal altruism.

Our analysis showed that cooperation and communication were important in creating reciprocal relationships. Cooperation was a signal representing cooperativeness (i.e., “I’m a cooperator”) ¹⁾. A player needed to cooperate to send a signal. Consequently, players paid the cost of signaling, thereby providing benefits to receivers. The signal is expected to be highly reliable, because the meaning of the signal depends strongly on the sending method (cooperation) ²³⁾. Conversely, communication in simple text messages^{*5} was not guaranteed to be reliable as a signal, because signaling cost was not incurred, and it provided little benefit to receivers, i.e., with such a low-cost signal, senders could lie at any time²³⁾. Interestingly, low-cost signals not guaranteed to be reliable emerged, along with reliable signals.

Human social grooming is one of the low-cost signals. Social grooming is the construction and maintenance of social relationships in a complex society¹³⁾. Apes groom each other as their social grooming¹⁶⁾. However, this is too costly for humans, because human group size is larger than ape group size; therefore, humans must invest time and effort in grooming others to create social relationships in large groups⁷⁾. Therefore low-cost social grooming (e.g., gaze grooming¹⁴⁾) and one-to-many grooming (e.g., gossip⁸⁾) would be expected to

^{*5} Players tended to convey enthusiasm, acknowledgement, and encouragement.

have evolved in humans. In the SNG too, low-cost signals (“messaging”) might be used to create social relationships between players, even though a reliable signal was used.

Similarly, as the above reciprocal behavior, players more frequently tended to respond to requests from cooperative players with them than to those from noncooperative players, even in a win-win situation, in which responding to a “help” request from others provides benefits to both the helper and the helped players. That is, cooperators acquired benefits for interacting with each other in such a situation. Conversely, noncooperators did not, because their “help” requests were received a lower priority than the cooperators’ requests. Consequently, the cooperators acquired greater benefits than the noncooperators. We can regard the effect of such cooperators’ behavior tendencies as punishment²⁰⁾ for noncooperators that may have decreased noncooperative behavior.

The present study provides quantitative evidence that the three mechanisms, reciprocal altruism, social grooming, and punishment, generate cooperation in an environment in which players can behave with fewer restrictions than in the theoretical and experimental studies. In addition, this trend was stronger in smaller groups.

We regarded the social environment of the SNG as static for simplification. However, in reality, new players come to this game every day, some players stop playing, and new social relationships are constructed. Simultaneously, the strength and kinds of social dilemmas change dynamically. Therefore, analysis of the dynamics of social relationships is a challenge for future research.

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§1 Game Information

We analyzed cooperative behavior in the SNG, “Girl Friend BETA.” Table 5 presents the game information.

In this SNG, players create individual decks of cards that they collect and then use their decks to perform tasks in the SNG. A powerful deck, constructed from powerful cards, provides an advantage for game play in various situations. The players’ primary motivation in the SNG is to obtain powerful cards. Players can obtain powerful cards as top-ranking rewards (see details later) or by casting lots called “Gacha.”

Players belong to groups in which they cooperate with each other to play the game efficiently; the groups were limited to 1-50 players. We filtered out players who do not belong to groups, because almost all active players belonged to groups to play effectively. Active players can create groups on their own. Others apply to join groups and then join a group after acceptance of the application by an administrator, who is typically a group founder. Players can leave a group at any time and apply to join a different group. Players observe their group members’ behavior (e.g., attack on common enemies (see details later)), because the game system shows their behavior on the game screen. Thus, the SNG meets conditions 1 and 2 for reciprocity.

This game system provides two communication methods, “messaging” between two players and posting on a “bulletin board,” which is provided for each group. We analyzed “messaging,” because it was used more often than the

Table 5 Game information

Developer and Publisher	CyberAgent Inc.
Service Name	Girl Friend BETA
URL	http://vcard.ameba.jp
Event Name	Cherry Blossom Viewing Party
Event Type	Raid Battle
Event Time Period	3/25/2013 16:00 to 4/8/2013 14:00
Analysis Time Period	4/5/2013 0:00 to 4/8/2013 14:00

“bulletin board.” Players use this function to send simple messages limited to 30 Japanese characters. It does not affect either senders or receivers negatively; nevertheless, its positive effects are also few. Every player can read messages of all other players on the respective receiver’s profile page at any time. It is used primarily one to one, but players can also send a message concurrently to their group members or to players who have joined a battle with them (see details later).

§2 Game Rules

Our analysis target was a raid event (Fig. 2), in which players attack large enemies^{*6} and acquire “event points.” Players competed in the rankings based on their event points, because they received better awards as their rankings increased.

Players conduct quests^{*7} to find enemies during an event. Players begin battles when they find an enemy and then attack the enemy to obtain points. However, enemies with very high hit points are strong, making it difficult for players to win these battles unaided. Thus, they can call for help from other group members, to win the battle. Players who helped had their point gain increased by 1.5 times. Therefore, players help their fellow group members to acquire more points.

Players’ point gains are proportional to the amount of damage caused during attacks, i.e., more powerful decks earn more event points. A player

^{*6} The enemy only has hit points as an attribute, meaning that players cannot be attacked by enemies. A player must attack an enemy to acquire event points at the expense of attack points.

^{*7} This is one of the basic actions in SNGs. A player may encounter an enemy on performing certain action.

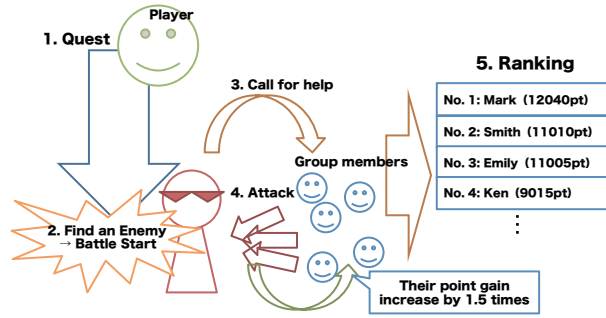


Fig. 2 Overview of raid event. A player conducts “quests” to find enemies (1). The player begins a battle upon finding an enemy and then attacks the enemy to obtain points (2). Enemies with very high hit points are strong; thus, they can call for help from other group members whom they have helped to win the battle (3). Players who helped had their point gain increased by 1.5 times (4). Players compete in rankings based on their points (5).

immediately acquires points upon attacking an enemy, even if the enemy is not defeated. However, a player cannot battle another enemy while already battling another enemy, and that enemies’ hit points increase with each battle; therefore, players must attack enemies repeatedly in the latter half of an event. Thus, a player who finds an enemy or helps a fellow group member must defeat the enemy before taking a next action, or wait until that the enemy leaves^{*8}.

Players increase the amount of damage caused during their attacks by launching “combo attacks,” alternate attacks by two or more players in which the players need to launch attacks within ten minutes after other players^{*9}. The longer a chain of combo attacks, the more acquisition points are acquired. Battling enemies together with fellow group members increases the effectiveness of acquisition points.

Players must use a quarter of their attack points to attack; thus, they can attack four times when their point totals are full. There are two methods for replenishing these points: wait for the points to replenish over time or use an item that costs 100 JPY (such items are also sometimes distributed in the game as rewards).

^{*8} The length of the disable time is set between one and two hours. It is too long to complete the rankings for middle- and higher-rank players, because other players progress in the rankings during their disabled time.

^{*9} If a player sequentially attacks an enemy then the attack is not count for the “combo attacks.” In addition, if players do not attack during ten minutes then their chain of combo attacks are reset to 0.

Table 6 Payoff matrix for the test scenario consisting of two players and an enemy with very few hit points. The player who attacks the enemy receives S , and the other player receives T . If neither player attacks the enemy, then each receives P . Attack by both players is impossible, because either player can defeat the enemy.

	Attack	Wait
Attack	$-, -$	S, T
Wait	T, S	P, P

Thus, players must use their resources (items and time) effectively to progress to a higher ranking, e.g., responding to a “help” request from their group members to acquire a point gain increase of 1.5 times, increasing the number of “combo attacks” to increase the amount of damage, and reducing the disable time. We defined payment efficiency as the event points per payment, as in game theory.

§3 The Test Scenario

It was impossible to track every cooperative behavior, because players can exhibit various behaviors in the SNG. Hence, we focused on one easily tracked cooperative behavior, and we regarded its frequency as players’ cooperativeness.

We focused on the following scenario based on these rules to define players’ cooperativeness.

- An enemy is attacked by a player and fellow group members.
- The enemy’s hit points are very few.

In this scenario, players who defeat the enemy will acquire only a few event points, because their attack power is higher than the enemy’s hit points. Thus, their behavior is not efficient for acquiring event points. By contrast, if the players’ attack power is lower than the enemy’s hit points, their behavior is efficient for acquiring event points. Furthermore, they cannot battle another enemy, if battle with one enemy is ongoing, and therefore must wait until they defeat the enemy to exhibit efficient behavior.

In simple terms, consider that two players battled an enemy in this scenario, where their relationship is represented in Table 6. The relationship between the variables is $T > S > P$ in this payoff matrix. Attack is not efficient, when S is less than T . However, if they do not attack the enemy, they waste

time by waiting for someone else to attack, i.e., P is lowest. It is not possible to cooperate both players in this scenario, because an attack on the enemy by either player immediately defeats the enemy. The values of this payoff matrix depend on each players situation, e.g., the differences between the two attack powers^{*10}. This asymmetric diversity satisfies condition 3 for reciprocity. In the scenario, both try to avoid the worst situation (i.e., they get P), but they also do not want to pay the cost to avoid the worst situation (i.e., they get S). This social dilemma is similar to the one in the “Leader game” (Table 1). In that game, Pareto efficiency is achieved when one cooperates, and the other does not. Then, the cooperator receives S , and the noncooperator T . That is, players receive a high payoff by sharing S and T on repeated plays of the game, a process known as ST reciprocity²⁸⁾. We recognized this cooperative behavior, which provided the payoff S from one to the other, as a cooperative behavior in this scenario.

Cooperative behavior is an inefficient attack, as shown in Table 6; thus we define a_{ij} as the attack efficiency indicator:

$$a_{ij} = e_{ij}/M(\mathbf{e}_i), \quad (5)$$

where e_{ij} are the event points in player i ’s j th attack and $M(\mathbf{e}_i)$ is the median of $\mathbf{e}_i = \{e_{i1}, \dots, e_{iN}\}$ (N is the frequency of player i ’s attacks). We considered cooperative behavior to be in the range of $a \leq 0.40$.

§4 The Test Scenario without Social Dilemma

We analyzed social behavior in a win-win situation in which players do not have a social dilemma, i.e., an enemy’s hit point remains sufficient. It is difficult for players to defeat the enemy alone in this situation. Therefore, they request “help” from their group members. If the group members respond to the request, then the helper and the helped players effectively acquire event points by creating a chain of combo attacks. In addition, the group members also have their point gain increased by 1.5 times. Thus, responding to a “help” request from group members provides benefits to helpers, irrespective of the one they help.

^{*10} In addition, it does not mean that the relationship between the payoffs is constant. If a player is about to go to sleep, then S is larger than T , because the attack points replenish the next morning.